DAYA BAY AD LIQUIDS

ATTENUATION LENGTHS AND PHYSICS IMPACT

JOHNNY GOETT

RPI

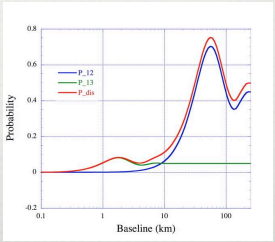
NEUTRINO OSCILLATIONS

$$|\nu_\alpha >= \sum_i U^*_{\alpha i} |\nu_i >$$

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & e^{-i\delta}\sin\theta_{13} \\ 0 & 1 & 0 \\ e^{-i\delta}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{23} & \sin\theta_{23} & 0 \\ -\sin\theta_{23} & \cos\theta_{23} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$P(\nu_\alpha \to \nu_\beta) = |\sum_i U^*_{\alpha i} e^{-i\frac{\Delta m^2_i x}{2E}} U_{\beta i}|^2$$



NEUTRINO OSCILLATIONS

$$|\nu_\alpha >= \sum_i U^*_{\alpha i} |\nu_i >$$

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}$$

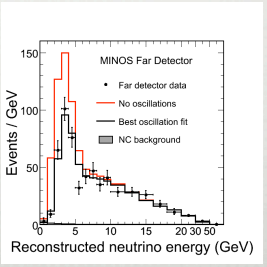
ATMOSPHERIC

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & e^{-i\delta}\sin\theta_{13} \\ 0 & 1 & 0 \\ e^{-i\delta}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{23} & \sin\theta_{23} & 0 \\ -\sin\theta_{23} & \cos\theta_{23} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\Delta M^2_{\text{atm}} = 2.43 \pm 0.13 \text{x} 10^{-3} \text{eV}^2, 68\% \text{C.L.}$$

$$\sin^2(2\theta) > 0.90, 90\% \text{ C.L.}$$

ADAMSON, 2008



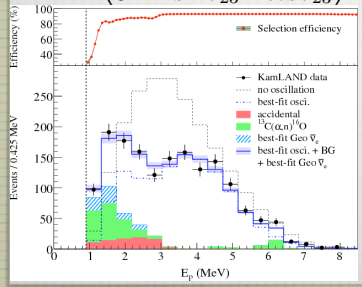
NEUTRINO OSCILLATIONS

$$|\nu_\alpha >= \sum_i U^*_{\alpha i} |\nu_i >$$

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & e^{-i\delta}\sin\theta_{13} \\ 0 & 1 & 0 \\ e^{-i\delta}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{23} & \sin\theta_{23} & 0 \\ -\sin\theta_{23} & \cos\theta_{23} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

SOLAR



$$\Delta M^2_{sol} = 7.58^{+0.14}_{-0.13}(stat)^{+0.15}_{-0.15}(syst) \times 10^{-5}\text{eV}^2$$

$$\tan^2\theta_{12} = 0.56^{+0.10}_{0.07}(stat)^{+0.10}_{-0.06}(syst)$$

ABE, 2008

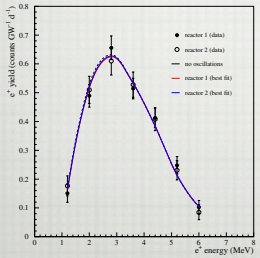
NEUTRINO OSCILLATIONS

$$|\nu_\alpha >= \sum_i U^*_{\alpha i} |\nu_i >$$

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix}$$

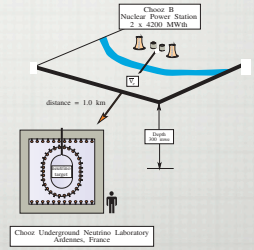
?

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & e^{-i\delta}\sin\theta_{13} \\ 0 & 1 & 0 \\ e^{-i\delta}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{23} & \sin\theta_{23} & 0 \\ -\sin\theta_{23} & \cos\theta_{23} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$



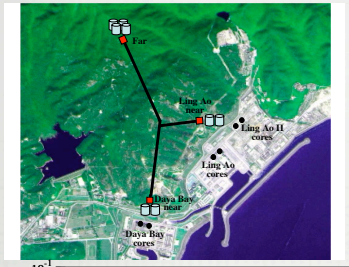
$$\sin^2(2\theta_{13}) \leq 0.1$$

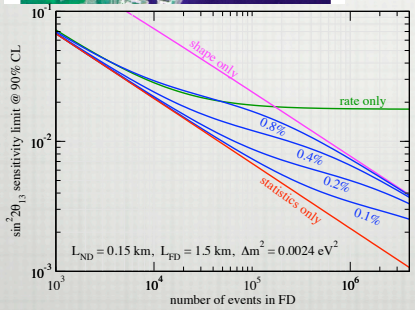
APOLLONIO,2003

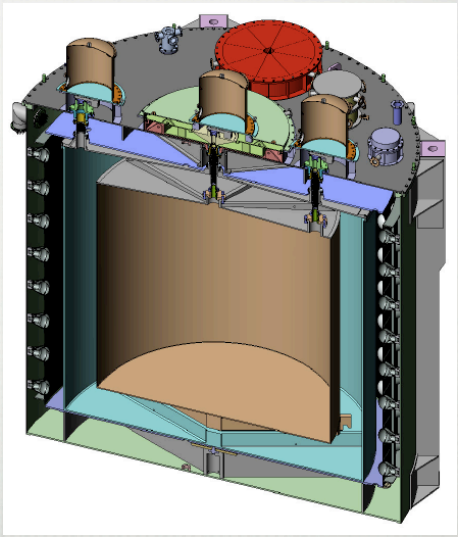


DAYA BAY

$$\left(\mathrm{n} \rightarrow \mathrm{p} + e^{-} + \bar{\nu}_e\right) \rightarrow \left(\mathrm{p} + \bar{\nu}_e \rightarrow \mathrm{n} + e^{+}\right)$$



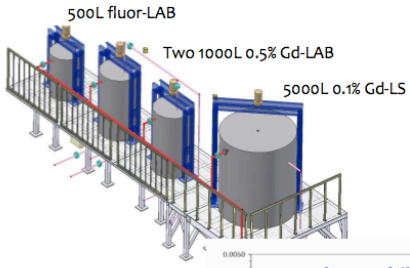




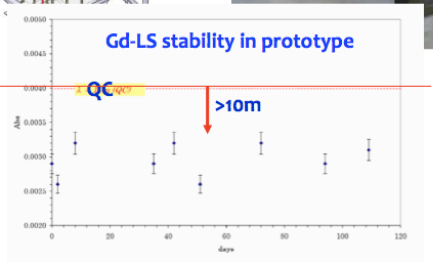
MEZZETO, ARXIV 1003.5800

LS + GDLS

Daya Bay experiment uses 200 ton 0.1% gadolinium-loaded liquid scintillator (Gd-LS)
Gd-TMHA + LAB + 3g/L PPO + 15mg/L bis-MSB



4-ton test batch production in March 2009



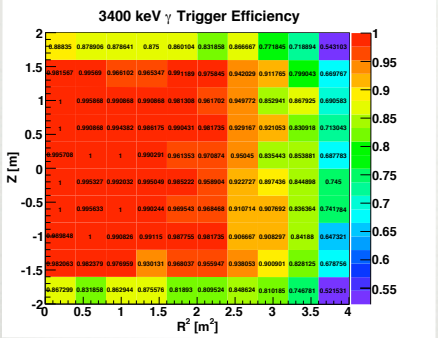
Gd-LS will be produced in multiple batches but mixed in reservoir on-site, to ensure identical detectors.

M. Yeh

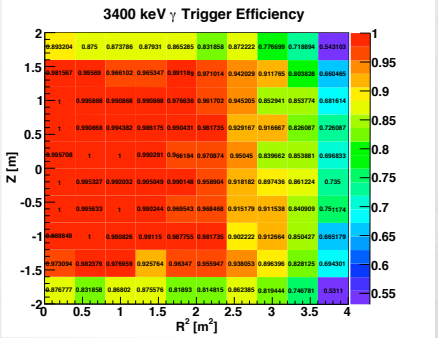
ATTENUATION LENGTH IMPACT

EFFICIENCY

5M

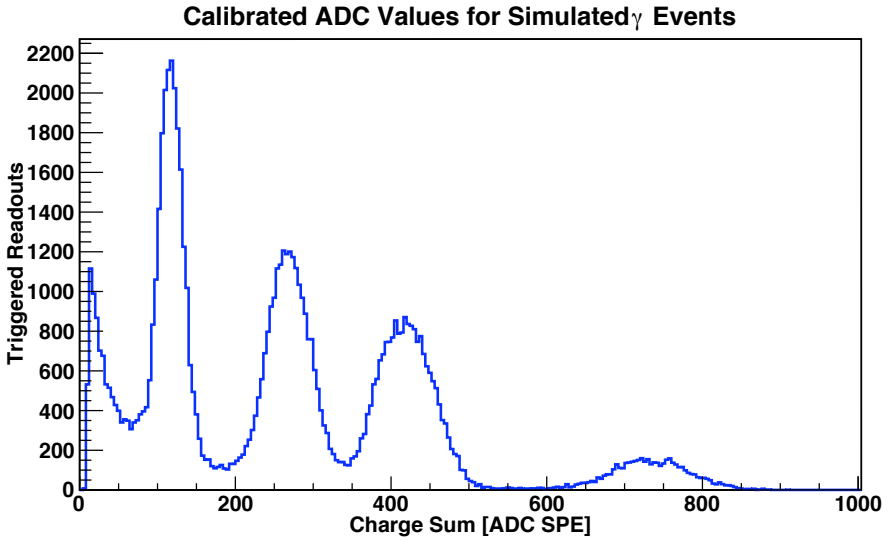


15M



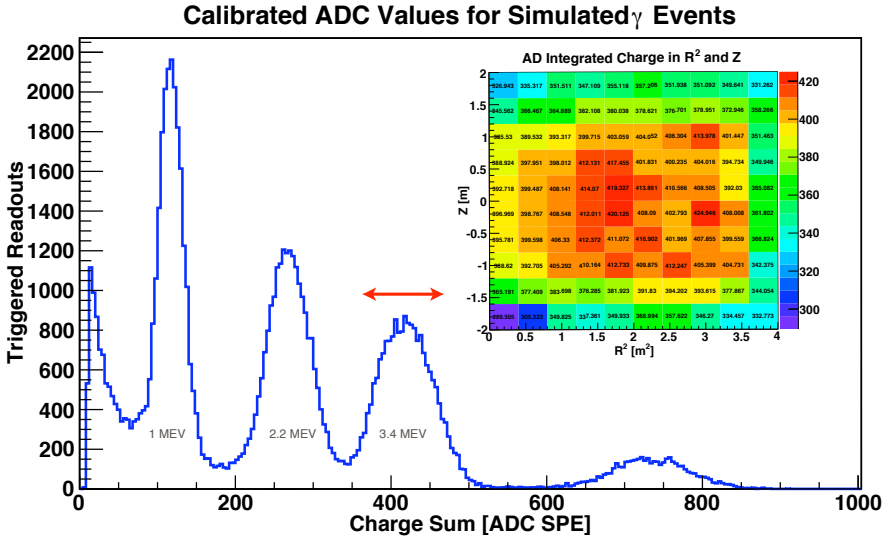
ATTENUATION LENGTH IMPACT

ENERGY SCALE

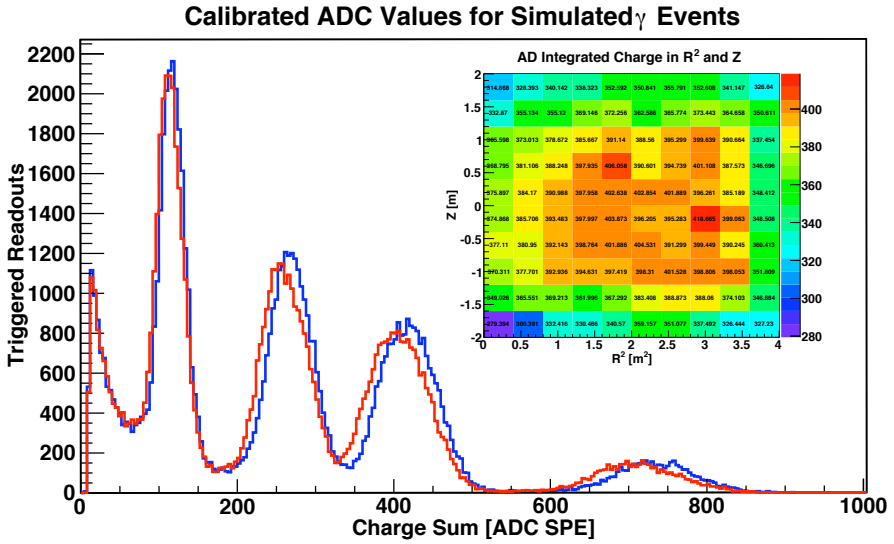


ATTENUATION LENGTH IMPACT

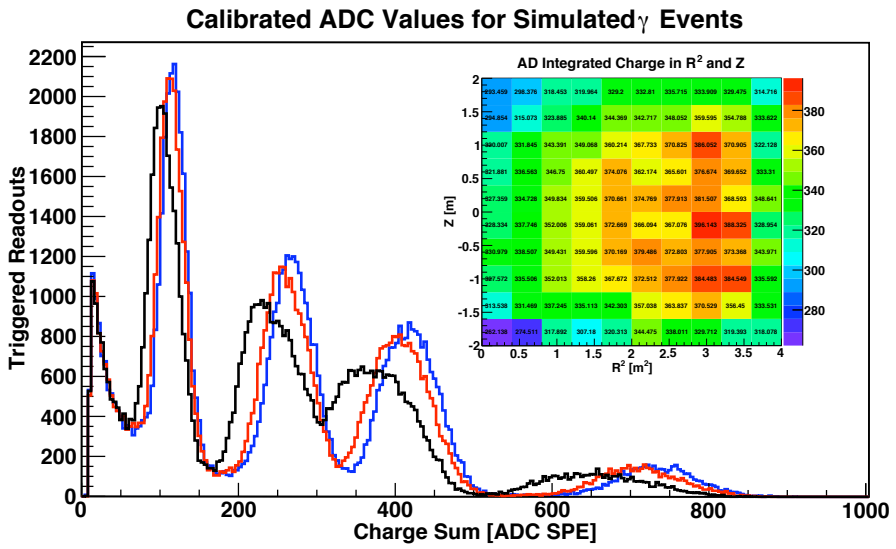
ENERGY SCALE



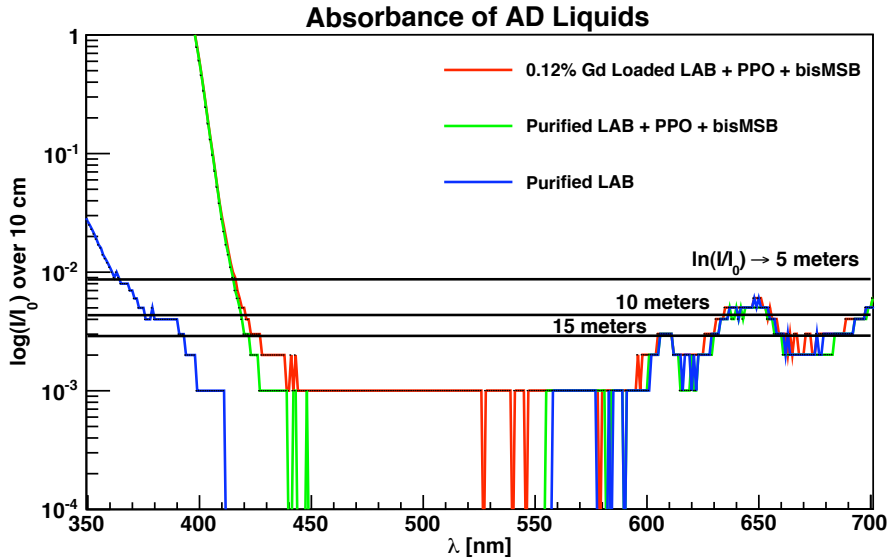
ATTENUATION LENGTH IMPACT

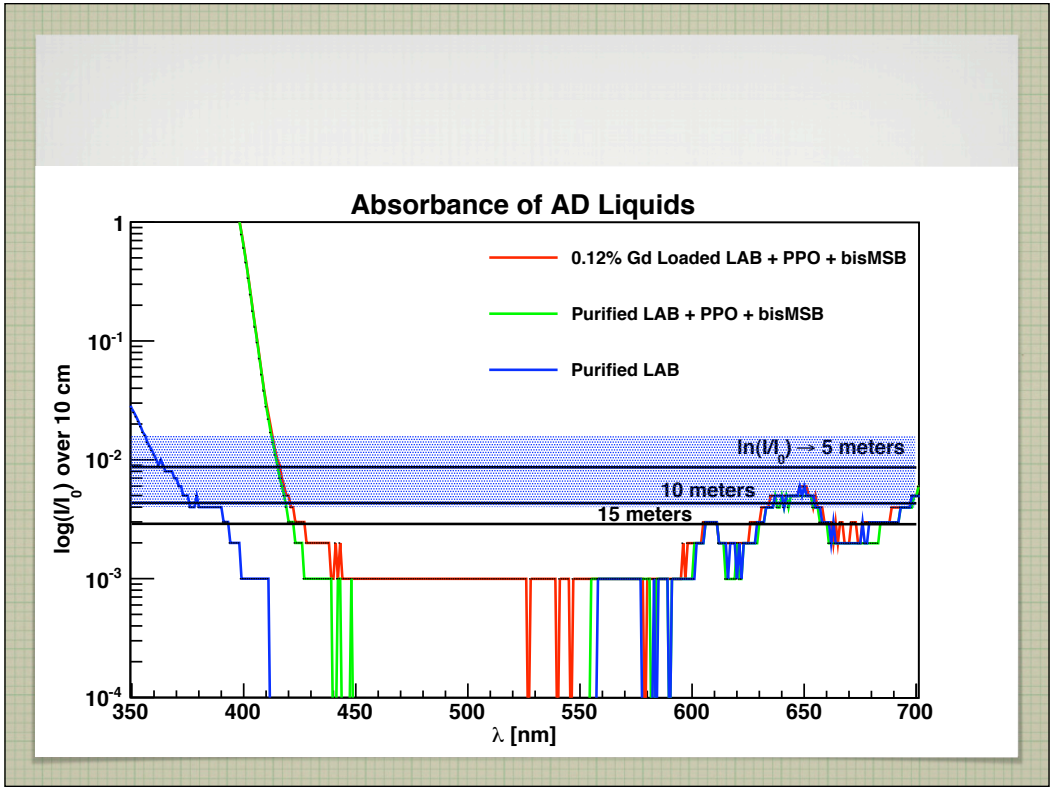


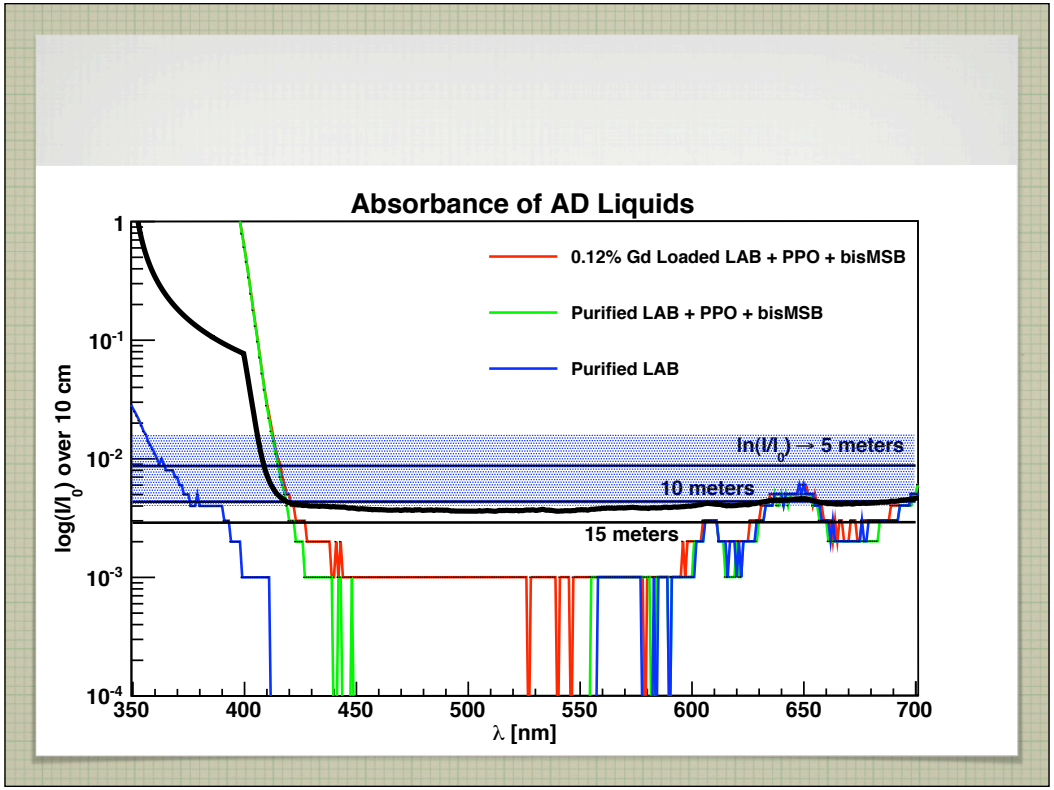
ATTENUATION LENGTH IMPACT



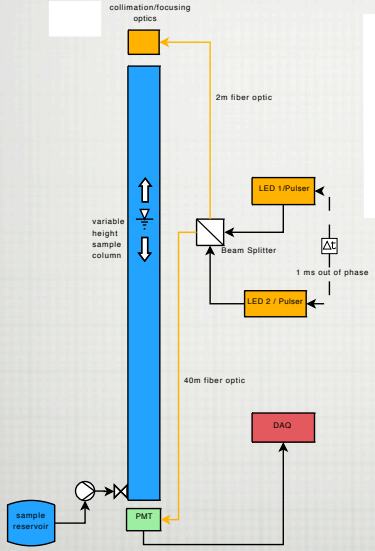
10 CM CELL ATTENUATION MEASUREMENTS

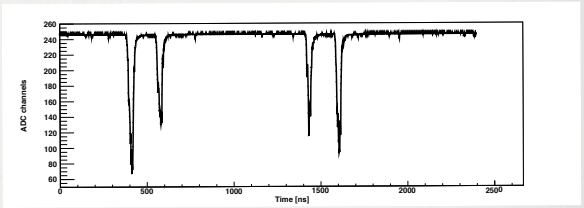


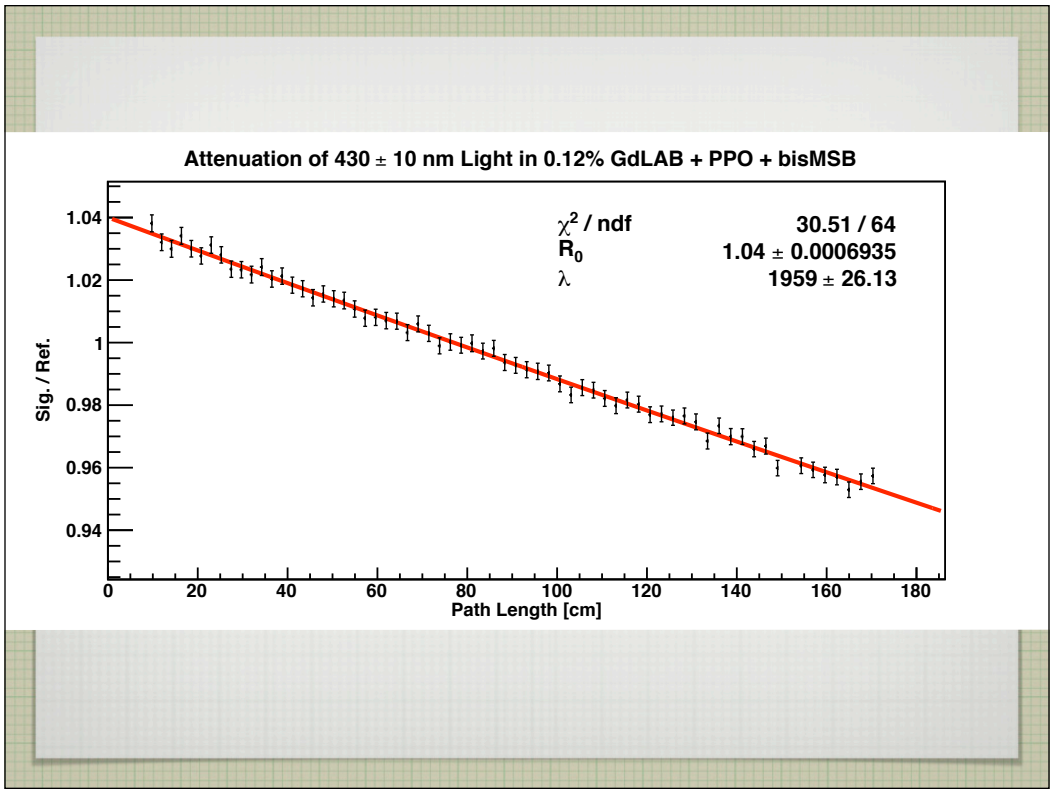

Absorbance of AD Liquids
0.12% Gd Loaded LAB + PPO + bisMSB
Purified LAB + PPO + bisMSB
Purified LAB
ln(I/I0) → 5 meters
10 meters
15 meters
log(I/I0) over 10 cm
λ [nm]
1
10-1
10-2
10-3
10-4
350
400
450
500
550
600
650
700

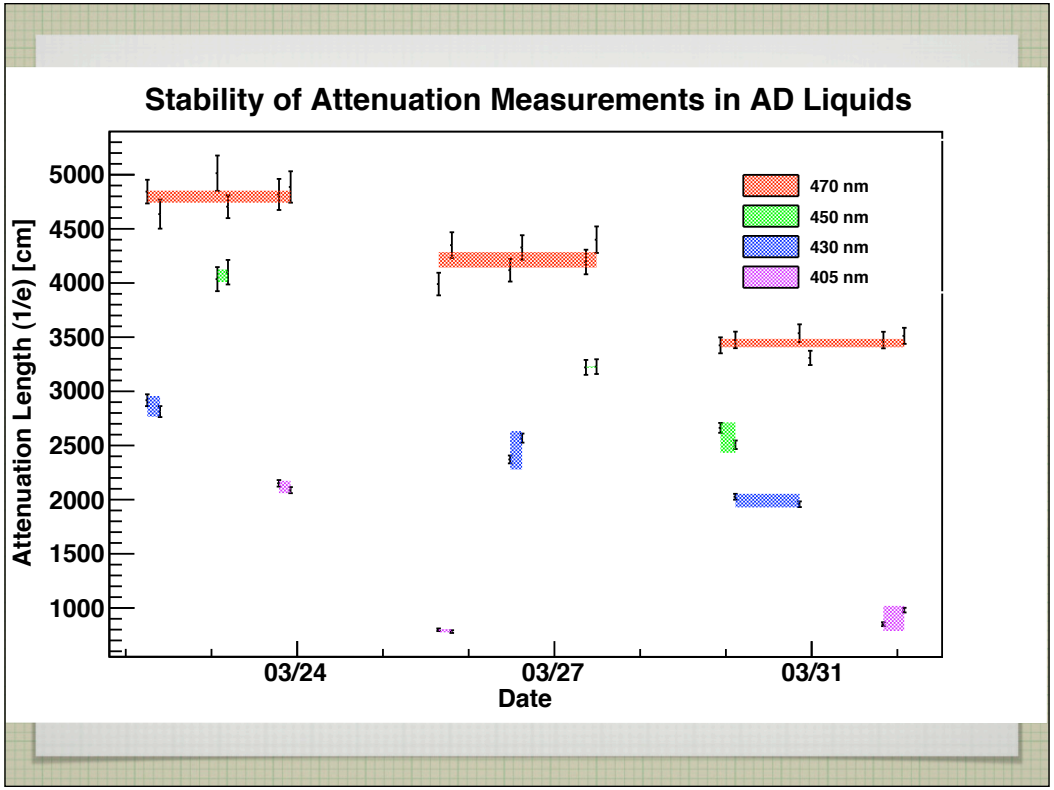

Absorbance of AD Liquids
0.12% Gd Loaded LAB + PPO + bisMSB
Purified LAB + PPO + bisMSB
Purified LAB
ln(I/I0) → 5 meters
10 meters
15 meters
log(I/I0) over 10 cm
λ [nm]
1
10-1
10-2
10-3
10-4
350
400
450
500
550
600
650
700

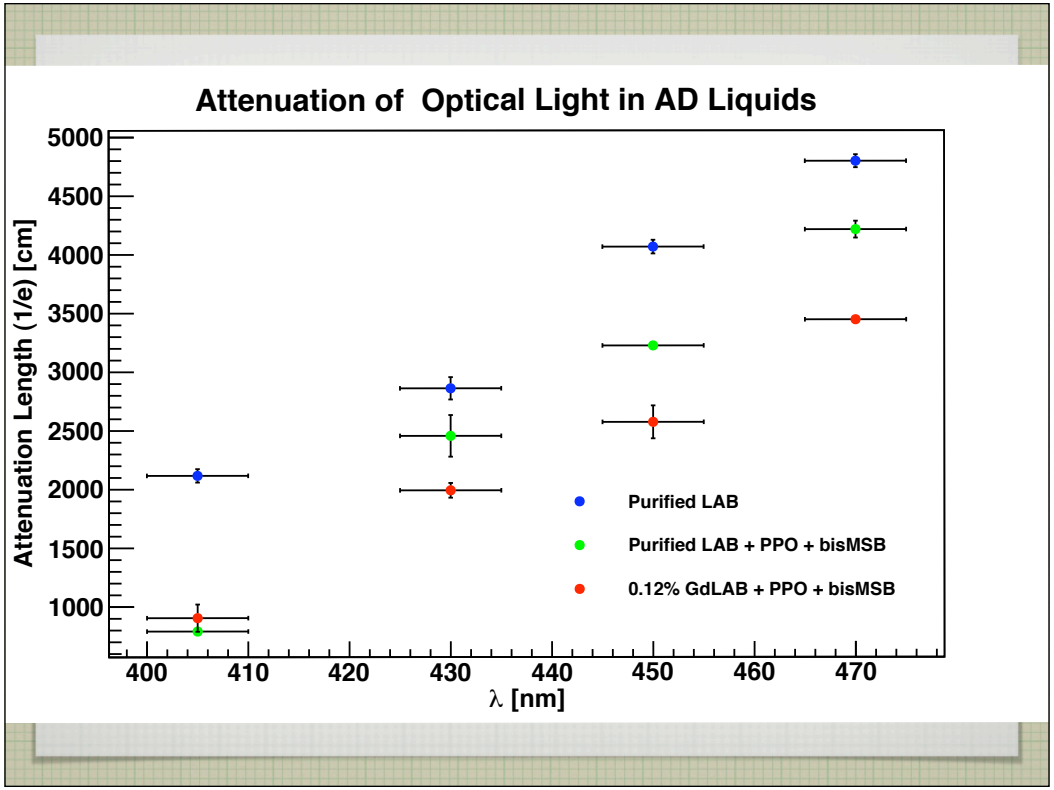
2M SYSTEM


collimation/focusing optics
2m fiber optic
LED 1/Pulser
variable height sample column
Beam Splitter
Δt
1 ms out of phase
LED 2 / Pulser
40m fiber optic
DAQ
sample reservoir
PMT


ADC channels
260
240
220
200
180
160
140
120
100
80
60
0
500
1000
1500
2000
2500
Time [ns]


Attenuation of 430 ± 10 nm Light in 0.12% GdLAB + PPO + bisMSB
χ² / ndf
30.51 / 64
R0
1.04 ± 0.0006935
λ
1959 ± 26.13
Sig. / Ref.
1.04
1.02
1
0.98
0.96
0.94
0
20
40
60
80
100
120
140
160
180
Path Length [cm]


Stability of Attenuation Measurements in AD Liquids
Attenuation Length (1/e) [cm]
5000
4500
4000
3500
3000
2500
2000
1500
1000
03/24
03/27
03/31
Date
470 nm
450 nm
430 nm
405 nm


Attenuation of Optical Light in AD Liquids
Attenuation Length (1/e) [cm]
5000
4500
4000
3500
3000
2500
2000
1500
1000
400
410
420
430
440
450
460
470
λ [nm]
Purified LAB
Purified LAB + PPO + bisMSB
0.12% GdLAB + PPO + bisMSB